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46 Advanced Diagnostics

After studying this chapter, you will be able to:

- Use advanced diagnostic techniques to troubleshoot difficult problems.
- Use scan tool snapshot and datastream values to find problems not tripping trouble codes.
- Use a breakout box to measure circuit values.
- Explain the principles of an oscilloscope.
- Summarize how to use waveforms to analyze the operation of sensors, actuators, ECU outputs, and other electrical-electronic devices.
- Evaluate ignition system waveforms.
- Summarize how to use an engine analyzer.

Earlier chapters explained how to diagnose problems using a scan tool, a multimeter, and various specialized testing devices. If these basic troubleshooting tools fail to pinpoint the source of the problem, you may need to use more complex diagnostic methods to find and fix the trouble.

This chapter summarizes advanced methods used to troubleshoot difficult-to-locate problems. It also introduces the operating principles of vehicle analyzers, with emphasis on using the oscilloscope.

Advanced Diagnostics

Strategy-based diagnostics involves using a consistent, logical procedure to narrow down the possible problem sources. Basically, the procedure involves verifying the complaint, making preliminary checks, reading service bulletins, performing service manual–recommended checks, repairing the problem, and rechecking system operation. See **Figure 46-1**

At one time or another, every technician encounters a problem that seems impossible to fix. He or she might replace a part that seems bad, only to find the same annoying symptoms when the repair is complete. The new part must be removed and further diagnosis

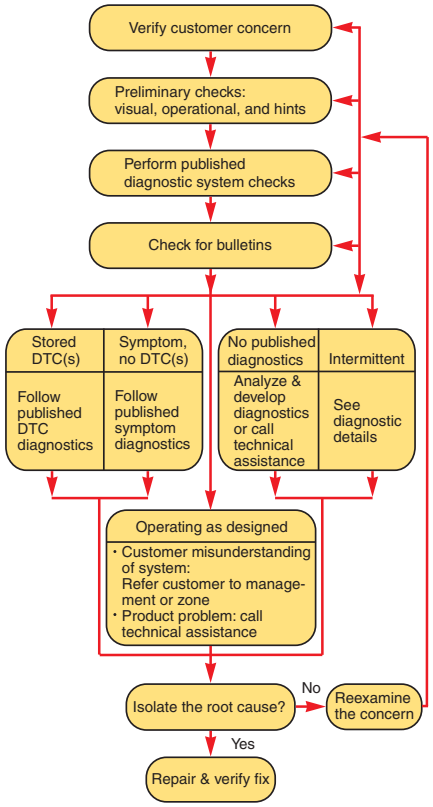


Figure 46-1. This chart shows basic steps of strategy-based diagnostics. Study the chart carefully. (General Motors)

completed until the real "culprit" is found. This is when advanced diagnostic techniques come in handy.

By learning a few advanced "tricks of the trade" (using datastream values, a breakout box, an oscilloscope, and an analyzer), even the most difficult problems can be located and corrected with minimal frustration.

When diagnosing problems, use your knowledge of system operation to determine which part could be malfunctioning and causing the symptoms.

For example, if an engine misses only when cold, think of which parts affect cold engine operation. You should think of the coolant temperature sensor, the intake air temperature sensor, and the cold start injector. These components are monitored and/or controlled by the ECM, which enriches the air-fuel mixture when the engine is cold.

Service manuals contain information to help facilitate troubleshooting. The chart shown in **Figure 46-2** summarizes the basic service procedures that can be performed to help find intermittent problems in one particular vehicle.

Vacuum and Pressure Gauge Tests

A ***vacuum gauge*** measures negative air pressure (pressure lower than atmospheric pressure) produced by the engine, fuel pump, vacuum pump, and other components. It is a valuable tool for determining engine condition and testing vacuum-actuated devices.

A ***pressure gauge*** measures positive pressures (pressures higher than atmospheric pressure) produced by the engine, turbocharger, fuel pump, or other device. It can be used to check for high exhaust system back pressure (restricted converter or system), abnormal fuel pressure, incorrect turbocharger boost pressure, and other problems. You must use your knowledge of system operation,

	Variable factor	Influential part	Target condition	Service procedure
1	Mixture ratio	Pressure regulator	Made lean	Remove vacuum hose and apply vacuum.
			Made rich	Remove vacuum hose and apply pressure.
2	Ignition timing	Crankshaft position sensor	Advanced	Rotate distributor clockwise.
			Retarded	Rotate distributor counterclockwise.
3	Mixture ratio feedback control	Oxygen sensor	Suspended	Disconnect oxygen sensor harness connector.
		ECM	Operation check	Perform on-board diagnostic system (On-board Diagnostic Test Mode II) at 2000 rpm.
4	Idle speed	IAC valve-AAC valve	Raised	Turn idle adjusting screw counterclockwise.
			Lowered	Turn idle adjusting screw clockwise.
5	Electrical connection (Electric continuity)	Harness connectors and wires	Poor electrical connection or improper wiring	Tap or wiggle.
				Race engine rapidly. See if the torque reaction of the engine unit causes electric breaks.
6	Temperature	ECM	Cooled	Cool with an icing spray or similar device.
			Warmed	Heat with a hair drier. **[WARNING: Do not overheat the unit.]**
7	Moisture	Electric parts	Damp	Wet. **[WARNING: Do not directly pour water on components. Use a mist sprayer.]**
8	Electric loads	Load switches	Loaded	Turn on headlamps, air conditioning, rear defogger, etc.
9	Closed throttle position switch condition	ECM	ON-OFF switching	Rotate throttle position sensor body.
10	Ignition spark position	Timing light	Spark power check	Try to flash timing light for each cylinder using ignition coil adapter (SST).

Figure 46-2. This diagnostic chart shows how different factors and parts can cause abnormal operating conditions. The technician can perform the service procedures listed to simulate intermittent problems. (Nissan)

the problem symptoms, and basic pressure testing methods to isolate hard-to-find problems.

A ***vacuum-pressure gauge*** reads both negative and positive pressures. It can be used to check all the previously mentioned systems.

To use a vacuum-pressure gauge (or a vacuum gauge) to check the engine, connect the gauge to a vacuum fitting on the intake plenum or manifold. Start the engine and note the reading on the gauge. Compare the gauge readings to normal readings. **Figure 46-3** shows typical vacuum gauge readings and explains what they mean.

To help pinpoint problems that cannot be duplicated in the shop, technicians will often mount the vacuum-pressure gauge in the passenger compartment and run a long hose to the vacuum fitting on the engine. This allows the vehicle to be driven while checking for intermittent vacuum or pressure problems. It also allows the technician to monitor engine and other system values under load. See **Figure 46-4.**

Figure 46-4. A pressure-vacuum gauge with a long section of vacuum hose is needed for road testing. The vacuum gauge will read turbocharger or supercharger boost pressures while vehicle is driven.

Normal engine reading
Vacuum gauge should have reading of 18-22 inches of vacuum. The needle should remain steady.

Burned or leaky valves
Burned valve will cause pointer to drop every time burned valve opens.

Weak valve springs
Vacuum will be normal at idle but pointer will fluctuate excessively at higher speeds.

Worn valve guides
If pointer fluctuates excessively at idle but steadies at higher speeds, valves may be worn allowing air to upset fuel mixture.

Choked muffler
Vacuum will slowly drop to zero when engine speed is high.

Intake manifold air leak
If pointer is down 3 – 9 inches from normal at idle, throttle valve is not closing or intake gaskets are leaking.

Carburetor or fuel injection problem
A poor air-fuel mixture at idle can cause needle to slowly drift back and forth.

Sticking valves
A sticking valve will cause pointer to drop intermittently.

Figure 46-3. Typical vacuum gauge readings and possible causes. (Sonco)

Figure 46-5. Always keep vacuum diaphragms in mind as a potential source of trouble. They can rupture, leak air, and not operate properly. A vacuum pump can be used to check the condition of the vacuum diaphragm.

Vacuum Pump Tests

A ***hand vacuum pump*** is commonly used to check vacuum-actuated devices and vacuum diaphragms. Since vacuum diaphragms are made of rubber, which can rupture or leak, they are a common source of performance problems.

To check a vacuum-actuated device, connect the vacuum pump to the fitting. Pump the handle and see if the device will hold a vacuum. If it leaks, the diaphragm or the device should be replaced, **Figure 46-5.**

Diesel Engine Testers

A ***diesel injection tester*** is a set of pressure gauges and valves used to measure injection system pressure. This tester will check fuel pump pressure and volume, injector operation (out of engine), lubrication system pressure, and other functions. If diesel injection pressures are not within specifications, repairs or adjustments are needed. Refer to **Figure 46-6.**

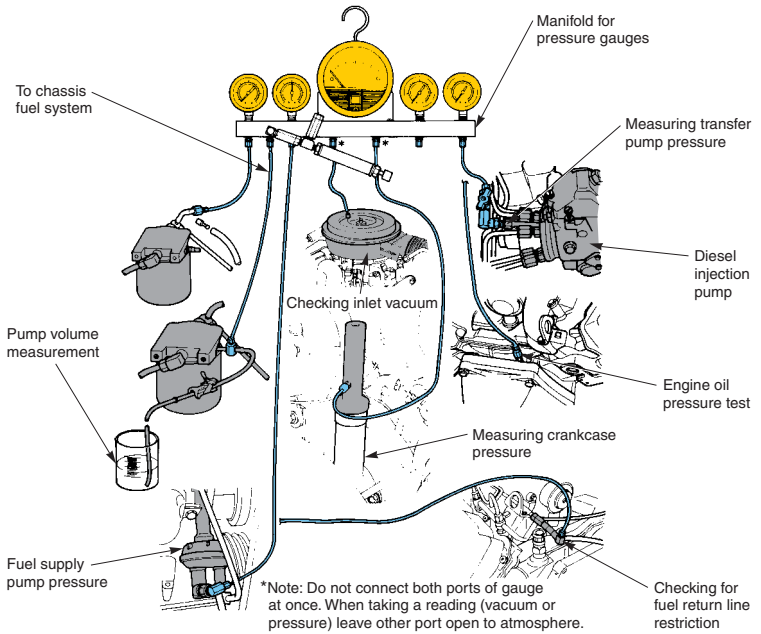

Manifold for pressure gauges
To chassis fuel system
Measuring transfer pump pressure
Diesel injection pump
Checking inlet vacuum
Pump volume measurement
Engine oil pressure test
Measuring crankcase pressure
Fuel supply pump pressure
*Note: Do not connect both ports of gauge at once. When taking a reading (vacuum or pressure) leave other port open to atmosphere.
Checking for fuel return line restriction

Figure 46-6. Diesel injection system testers can perform several tests. Note the various test connections. (Ford)

Warning!
The operating pressures in a diesel injection system are high enough to cause serious injury. Even a small fitting leak can allow high-pressure fuel to spray out and puncture your skin or eyes.

A ***glow plug test harness*** can be used to find the cause of a cold start or rough idle problem in a diesel engine. The harness is connected to each glow plug, one at a time. Then, the ohmmeter is used to check the resistance of each glow plug. After a period of engine operation, the resistance of each glow plug is checked again. Combustion will increase glow plug temperature, affecting its resistance. An unequal change in glow plug resistance (temperature) indicates that a cylinder is not firing.

Advanced Scan Tool Tests

In addition to retrieving trouble codes, modern scan tools can be used for advanced diagnostic procedures. For example, the scan tool can take a "picture" of operating parameters at the moment a problem occurs, display "live" operating values as an engine is running, and check actuators for proper operation.

Scan Tool Snapshot

A scan tool ***snapshot*** is an instantaneous reading of the operating parameters that are present when a problem occurs. This feature is often used when a problem is hard to find or when intermittent troubles are present. Most scan tools can be programmed to automatically take a snapshot of operating parameters whenever a diagnostic trouble code is set. If desired, the snapshot feature can be triggered manually, allowing the use of the snapshot even when the vehicle does not generate a trouble code.

The manual capture feature requires you to monitor operating conditions and to press a button on the scan tool when the problem occurs. For example, if a car only acts up when driving at a specific highway speed, drive the vehicle at the trouble-causing speed and scan under these conditions. When the symptom occurs (engine misses), press the appropriate scan tool button to capture the operating values while the problem is happening.

After returning to the shop, look for any operating parameter that is almost out-of-specs. The operating parameter may not be tripping a trouble code, but it may be affecting vehicle operation. Sometimes, two or more electrical values can be almost out-of-specs.

By using the information provided by the snapshot feature, you can often determine what is causing the problem. You might have two sensors ready to fail, a poor electrical connection in combination with a mechanical failure, etc.

Scan Tool Datastream Values

Scan tool datastream values are "live" electrical values measured with the vehicle running and, in some cases, being driven. They almost eliminate the need for a breakout box or pinpoint measurements of electrical values. You can read the scan tool screen to see weak values or values that are almost out of specs. In most cases, you can choose which datastream values you want the scan tool to display. For example, you may want to look only at the inputs to the ECM.

If you have a performance problem but no trouble codes have been set, study the datastream values. Values that are almost out of specifications may signal a problem area. Datastream values give added information for finding troublesome problems. **Figure 46-7** gives a few datastream values that can be read by a scan tool.

Scan Tool Actuator Tests

Most scan tools can switch computer-controlled actuators on and off. This allows the technician to verify the operation of these components. For example, a scan tool can be used to fire an ignition coil, control the idle speed motor, or disable a fuel injector.

The scan tool can also be used to perform a power balance test. This test involves disabling a fuel injector or spark plug in a specific cylinder while monitoring the corresponding rpm drop. Power balance tests are detailed later in this chapter.

Checking Computer Terminal Values

Computer terminal values can be tested at the metal pins of the ECM. A digital VOM can be used to read terminal voltage and resistance values. These readings can then be compared to known good values. Often, the readings are taken with one or more wiring harnesses connected to the ECM. This eliminates the need to unplug connectors when making electrical measurements.

Figure 46-8 shows ECM terminal voltages for a specific vehicle. Note how the pin numbers correspond to certain circuits and electrical values.

Caution!
Never connect a low-impedance (resistance) analog meter or test light to a computer system unless instructed to do so by the service manual. A low-impedance meter or tester could draw enough current to damage delicate electronic devices.

Using a Breakout Box

A ***breakout box*** allows you to check electrical values at specific pins on an ECM or in the system the ECM controls. It is one of the last tools used in diagnostics, as it is time consuming, **Figure 46-9.**

The breakout box is connected in parallel with the ECM wiring harness. An inline connector is provided for plugging the test box into the wiring harness, usually at the ECM connector.

Then, a multimeter is used to touch specific terminals on the breakout box. The measured circuit values

DATASTREAM VALUES

For Cold Key On, Cold Idle and Hot Idle: Vehicle in PARK, A/C turned OFF, no power steering load, all ACC's OFF, Brake Pedal Released. For 55 MPH Cruise: Vehicle in Drive 4, A/C turned ON and no power steering load, compare data after driving for approximately 1 mile.

Scan Tool Parameter	Display Units	Data List	Cold Key ON	Cold Idle	Hot Idle	55 MPH Cruise
Engine Speed	RPM	ENG 1	0	Within 80 RPM of Desired Idle	Within 80 RPM of Desired Idle	1730
Desired Idle	RPM	ENG 1	0	700 to 1200	550 to 675	720
MAF	gms-sec	ENG 1	0.0	9.8 to 11.0	5.0 to 6.0	20 to 28
TP Sensor	V/°	ENG 1	0.63/1.7	.60 mV/ 0.8°	.60 mV/ 0.8°	1.06/11.0
ECT	°C	ENG 1	80° C	–20° C to 50° C	90° C to 110° C	90° C to 110° C
IAT	°C	ENG 1	80° C	–20° C to 50° C	0° C to 90° C	0° C to 90° C
MAP	kPa/V	ENG 1	97/4.63	30 to 50 kPa 1.50 V @ 38 kPa	30 to 50 kPa 1.50 V @ 38 kPa	64/2.88
BARO	kPa/V	ENG 1	97/4.65	85 to 103 kPa	85 to 103 kPa	98/4.69
TP Angle	%/°	ENG 1	0%/0.0°	0%/0.0°	0%/0.0°	11%/8.6°
Engine Load	%	ENG 1	0%	1 to 5%	1 to 5%	13%
Engine Speed	RPM	ENG 1	0	Within 80 RPM of Desired Idle	Within 80 RPM of Desired Idle	1730
IAC Position	counts	ENG 1	160	Varies	30 to 80	100
Inj. PWM Bank 1	ms	ENG 1	0.0	3.75 to 4.50	3.20 to 3.75	5.1 ms
Inj. PWM Bank 2	ms	ENG 1	0.0	3.75 to 4.50	3.20 to 3.75	5.2 ms
HO_2S Bn 1 Sen. 1	mV	ENG 1	67	Varies	Varies	Varies
HO_2S Bn 2 Sen. 1	mV	ENG 1	111	Varies	Varies	Varies
Rich to Lean Status Bn 1 Sen. 1	Lean/Rich	ENG 1	Lean	Varies	Varies	Varies
Rich to Lean Status Bn 2 Sen. 1	Lean/Rich	ENG 1	Lean	Varies	Varies	Varies
HO_2S Bn 1 Sen. 2	mV	ENG 1	45	Varies	Varies	Varies
HO_2S Bn 1 Sen. 3	mV	ENG 1	156	Varies	600 mV or more	600 mV or more
Rich to Lean Status Bn 1 Sen. 2	Lean/Rich	ENG 1	Lean	Varies	Varies	Varies
Rich to Lean Status Bn 1 Sen. 3	Lean/Rich	ENG 1	Lean	Varies	Varies	Varies
Fuel Trim Cell	Number	ENG 1	0	16	16	5
Fuel Trim Learn	Disabled/ Enabled	ENG 1	Disabled	Disabled	Enabled	Enabled
Shrt Term FT Bn 1	%	ENG 1	0%/128	–2.0 to 2.0	–3.0 to 3.0	–6.0 to 6.0

Figure 46-7. Scan tool datastream values can be helpful when you have performance problems but no trouble codes. Datastream values are electrical values detected by the ECM. If values from a pinpoint test do not match datastream values, suspect wiring or ECM problems.

ECM TERMINAL VOLTAGE
5.0L (V.I.N. H)

This ECM voltage chart is for use with a digital voltmeter to further aid in diagnosis. These voltages were derived from a known good car. The voltages you get may vary due to low battery charge or other reasons, but they should be very close.

The following conditions must be met before testing:
• Engine at operating temperature • Closed loop • Engine idling (for "engine run" column)
• Test terminal not grounded • Scanner not installed

Voltage Key "On"	Voltage Engine Run	Voltage Circuit Open				Voltage Key "On"	Voltage Engine Run	Voltage Circuit Open
0	0	0	Sensor return	22	1	Baro sensor signal decreases with altitude	4.75	4.75	*.5
5	5	5	5V reference	21	2	TPS sensor signal	*1.0 †5.0	*1.0	5.0
.5–.65	3–5	*.5	Vacuum sensor output	20	3	Coolant temp. sensor signal	*2.5	*2.5	5.0
12	4-7 (var.)	*.5	PWM EGR solenoid	19	4	Air control solenoid	12.5	*1.0	*.5
12	5-10 (var.)	*.5	M/C solenoid	18	5	Diagnostic test term	5	5	5
*.5	*.5	12	3rd Gear switch	17	6	A/C W.O.T. cutout (5.7L)	12	14	*.5
**10	**11	10	VSS signal	16	7	Coolant temp. sensor return	0	0	0
			Not used	15	8	Not used			
*.5	*.5	1.7	Oxygen sensor–LO	14	9	Oxygen sensor–HI	.3–.45	.1–.9 (var.)	.3–.45
*.5	*.5	*1.0	Dist. ref. pulse–LO	13	10	Dist. ref. pulse–HI	*.5	1–2 (var.)	*.5
*.5	1–2 (var.)	*.5	EST	12	11	IGN. module bypass	*.5	3.7	*.5
			Not used	J	K	Not used			
*.5 P/N 12 D/R	*.5 P/N 14 D/R	12	Park/neutral switch	H	L	ESC (5.0L)	7-10	7-10	*.5
10	*.5	*.5	"Check engine" lamp	G	M	Not used			
			Not used	F	N	4th gear switch if used	*.5	*.5	12
12	*1.0	*.5	Throttle kicker	E	P	Trans converter clutch solenoid	12	14	*.5
			Not used	D	R	Trouble code memory power	12	14	*.5
12	14	*.5	IGN 1 power	C	S	Not used			
12	14	*.5	Air switching solenoid	B	T	Not used			
0	0	0	Ground (to engine)	A	U	Ground (to engine)	0	0	0

* = Value shown or less than that value
† = Wide open throttle
(var.) = variable
P/N = Park or Neutral
D/R = Drive or Reverse
** = If less than 1V rotate drive wheel to verify

Figure 46-8. The service manual will usually specify the electrical values that should be present at each terminal of the computer connector. (General Motors)

Figure 46-9. A breakout box is usually the last tool used to find performance problems. It is connected to the wiring harness in computer system. Then a multimeter can be used to check terminals on the breakout box for actual operating voltages, resistance, and current values. They can be compared to known good values or to datastream values to find the cause of the problem. (OTC Div. of SPX Corp.)

are compared to the manufacturer's specifications. If the measured values are not within specifications, you usually have a defective component or a wiring problem. For example, if a reference voltage out of the ECM is low, the ECM is bad or the wiring between the ECM and the breakout box is faulty.

Isolating Electromagnetic Interference

Electromagnetic interference (EMI), or radiation interference, occurs when an induced voltage enters another system's wiring. Sources of EMI can include loose, misrouted, or unshielded spark plug wires; police and CB radios; and aftermarket accessories.

In the past, electromagnetic interference was limited to noise in the radio speakers. In late-model vehicles, EMI can cause a computer-controlled system to malfunction.

For example, induced voltage from a loose spark plug wire could enter a sensor wire. This unwanted voltage would then enter the computer as false data. Numerous computer malfunctions or false outputs could result. See **Figure 46-10.**

To isolate the source of electromagnetic interference, try turning off or disabling circuits or devices. If, for example, removing the drive belt from the alternator corrects the problem, suspect problems inside the alternator. If the problem only occurs with the heated windshield turned on, check components within the heated windshield circuit.

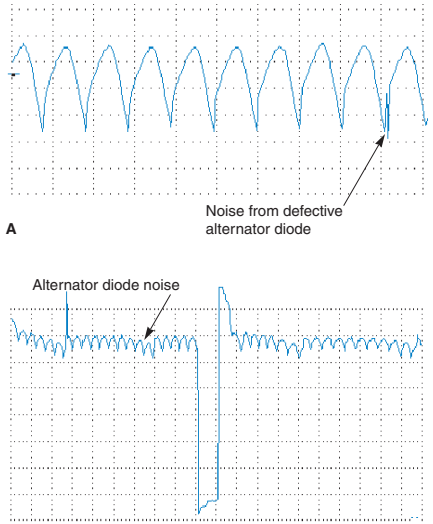


Figure 46-10. A—Electromagnetic interference can come from a variety of sources and can cause major problems. This waveform is caused by a defective alternator diode. B—This is the injector pulse waveform from the same vehicle. Note the hump pattern similar to the alternator pattern. (IATN)

You can use a small transistor radio to find induced voltage sources. Turn the radio on and set it on the AM band, but do not tune it to a station. If the shop is equipped with fluorescent lights, turn them off or test the vehicle outside, away from power lines and any other sources of EMI.

Move the radio around the engine compartment and under the dash with the engine running. If EMI noise (static) is present, a popping or cracking noise will be produced by the transistor radio. You can also use a car antenna cable and the car radio as a "noise sniffer." See **Figure 46-11.**

To correct an EMI problem, you must stop the source of the interference (replace leaking spark plug wire, use suppressing condenser, etc.) or shield the affected system's wiring from the interference (reroute the sensor wire or wrap the wire with foil-type tape, for example).

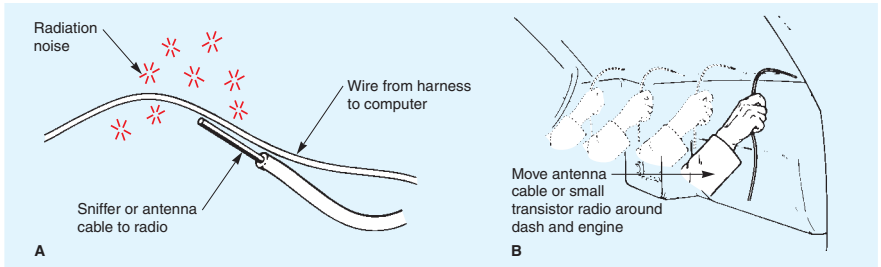

Radiation noise
Wire from harness to computer
Sniffer or antenna cable to radio
A
Move antenna cable or small transistor radio around dash and engine
B

Figure 46-11. A—Electromagnetic interference can be caused by ignition secondary voltage, leaking diode in alternator, and other sources of voltage spikes or magnetic field. B—A cheap transistor radio or an extra antenna cable connected to vehicle's radio will "listen" or "sniff" for source of interference. Radiation can upset operation of computer sensor signals and car radio. (General Motors)

Using a Digital Pyrometer

A ***digital pyrometer*** is an electronic device used to measure temperature. Measuring temperature can help you verify scan tool readouts and find hard-to-locate problems. It is handy for advanced diagnosis of various systems and components. A digital pyrometer can be used to check:

- Engine operating temperature.
- Exhaust temperature.
- Coolant temperature.
- Sensor temperature.
- Ambient temperature.
- Air conditioning outlet temperature.

You can test a temperature sensor while it is still in the engine by checking pyrometer readings against sensor resistance when the engine is cold and again after it warms. Touch the pyrometer's probe to the sensor to get a reading of its operating temperature. This will let you compare sensor temperature and resistance readings with manual specifications.

Finding Temperature-Related Performance Problems

When an engine performance problem occurs only at a specific temperature, suspect electronic parts. Electronic circuits, especially ignition control modules, can be affected by temperature extremes.

To check a component for problems affected by temperature, use a heat gun to warm the component or a can of freeze spray to cool the unit. If the problem occurs with the temperature change, the unit is at fault and should be replaced. See **Figure 46-12.**

Figure 46-12. When intermittent engine problems appear to be caused by heat, cold, or period of engine operation, suspect electronic control circuits in ECMs. A—Freeze spray directed onto the ECM may cause or solve engine performance problem. If it does, replace the ECM. B—If engine stops running when air from the heat gun is directed onto the ECM, you have found problem sources. Do not overheat ECM, however, or you could damage it.

Caution!
Do not apply too much heat to an electronic module. Excessive heat can damage components. Only match the engine operating temperature of about 200°F. (93°C). Use a digital thermometer to monitor the temperature when heating the unit.

Using a Dynamometer

A ***dynamometer,*** often referred to as a ***dyno,*** is used to measure an engine's power output and performance. By loading the engine, the dynamometer can check engine acceleration, maximum power output, and on-the-road performance characteristics. **Figure 46-13** shows a chassis dynamometer.

If you are having trouble finding a driveability problem, you might perform diagnostic tests while operating the vehicle on a dynamometer. This will let you simulate any condition that causes the problem.

For example, you could connect a five-gas exhaust analyzer to the tailpipe and operate the vehicle under load on the dynamometer, **Figure 46-14.**

You can also shift the vehicle through each gear, accelerate to the speed at which the problem occurs, walk around the vehicle to listen for abnormal noises, or connect listening devices—all while simulating driving conditions on the dyno.

Using an Oscilloscope

An ***oscilloscope,*** often called a ***scope,*** is a piece of test equipment that displays voltages in relation to time. When connected to circuit voltage, the scope produces a line on a cathode ray tube or a liquid crystal screen. The line illustrates the various voltages present in the circuit over short periods of time.

By comparing the scope pattern (line shape) to a known good pattern, the technician can determine whether something is wrong in the circuit. An oscilloscope is usually a major component of an analyzer. However, it may be mounted by itself on a small, roll-around cart, or it may be part of a hand-held scan tool or multimeter. See Figure **46-15.**

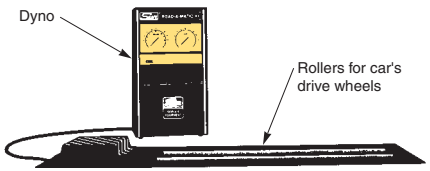


Figure 46-13. A chassis dynamometer will measure engine power output under road conditions. It will also load the engine while other tests are performed. (Sun Electric Corp.)

Figure 46-14. A five-gas analyzer is often used to check the content of engine exhaust gases. This will give added information for finding the source of a performance problem when operating a vehicle on a dynamometer. (OTC Div. of SPX Corp.)

Reading the Scope Screen

The ***scope screen*** can give instructions, display voltages as a trace, or give other values as digital displays. The oscilloscope's ability to draw a ***trace,*** or pattern of circuit voltages, for very short time spans makes it very useful for testing ignition and computer system performance. You should learn to recognize good scope patterns. Then, you can easily detect scope patterns that indicate problems.

Figure 46-15. This hand-held scan tool also functions as an oscilloscope. It can display voltages in relation to time. Note the scope pattern on the screen.

Voltage is shown on the scope screen along the vertical (up and down) axis, or scale. Voltage values are given on the right and left borders of the screen. See **Figure 46-16.**

With the controls set on kV, the numbers on the screen represent kilovolts. One kV equals 1000 volts; 5 kV equals 5000 volts; etc. If a line on the scope screen extends from zero to 7 kV, the scope is reading 7000 volts.

If the scope is set to read 0–10 volts for checking the ECM and its sensors, a line five divisions tall would indicate 5 volts. Similarly, a waveform five divisions tall would be a reading of 5 volts peak-to-peak (from the top of the positive trace to the bottom of the negative trace).

Voltage is the most commonly used value on a scope screen. As voltage increases, the trace line on the scope moves up. As voltage drops, the trace line moves down a proportionate amount.

Scope time is given on the horizontal scale of the scope screen in degrees, milliseconds, or duty cycle.

Different scales may be given on the bottom of the screen for four-, six-, or eight-cylinder engines. These scales are calibrated in degrees of distributor rotation. Degrees may also be given as a percentage, for quick reference to any number of cylinders.

The scope screen may also have a milliseconds scale for measuring actual time. This makes it possible to measure how long each spark plug fires in milliseconds.

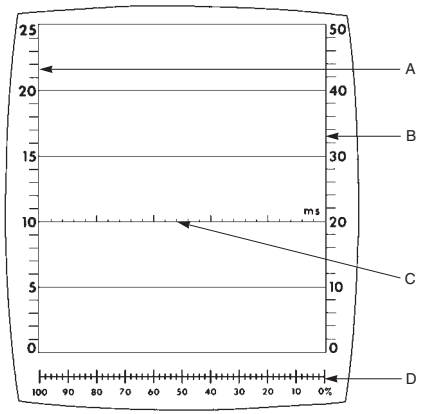


Figure 46-16. Scales on an oscilloscope screen allow you to measure voltage and time accurately. A—0–25,000 volt scale. B—0–50,000 volt scale. C—Scale for measuring time in milliseconds. D—Scale for measuring in degrees. (Sun Electric Corp.)

A certain amount of time is needed to properly ignite and burn the air-fuel mixture.

Scope Sweep Rate

Scope sweep rate is the frequency or time division shown on the screen during each test. The sweep rate adjustment affects the horizontal, or time, measurement. The scope sweep rate must be set to match the waveform frequency to be analyzed. Sweep rate is commonly given in milliseconds (ms).

A *low scope sweep rate* will compress the waveform, and too much information will be shown at once. A *high sweep rate* will expand the waveform, and only a small section of the complete waveform will be displayed.

Trial and error adjustment of sweep rate is commonly used. The sweep rate knob, or sweep knob, (time/division) on the scope is turned until the desired waveform is displayed on the screen. Compare the waveform pattern on the scope to a known good pattern.

Ignition System Patterns

A vehicle's ignition system is designed to produce wide fluctuations in voltage. When an ignition system is functioning properly, these voltages will be within specifications.

A component with higher-than-normal resistance (open spark plug wire, for example) would be indicated on the scope as a higher-than-normal voltage trace. The high resistance would produce a high voltage drop. A shorted component (fouled spark plug) would have low resistance and would produce a lower-than-normal voltage trace.

An oscilloscope's controls allow it to display either the primary (low-voltage) pattern or the secondary (high-voltage) pattern of the ignition system. The scope patterns are similar, but important differences should be understood.

To introduce the basic sections of a scope pattern, the primary and secondary patterns for *one cylinder* will be explained. More complex patterns for specialized tests will be covered later in this chapter.

Primary Scope Pattern

The ***primary scope pattern*** shows the low-voltage, or primary-voltage, changes in an ignition system. A primary scope pattern is shown in **Figure 46-17.**

The primary ignition pattern has three sections: firing, intermediate, and dwell. Note how the voltages change in each section of the pattern.

The ignition secondary circuit cannot work properly unless the primary circuit is in good condition. A problem in the primary circuit will usually affect the secondary circuit. For this reason, the secondary circuit pattern is *checked more often* than the primary pattern.

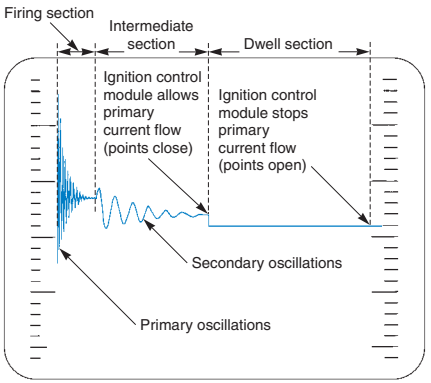

Firing section
Intermediate section
Dwell section
Ignition control module allows primary current flow (points close)
Ignition control module stops primary current flow (points open)
Secondary oscillations
Primary oscillations

Figure 46-17. Typical primary waveform for an ignition system. Study the various sections of the trace.

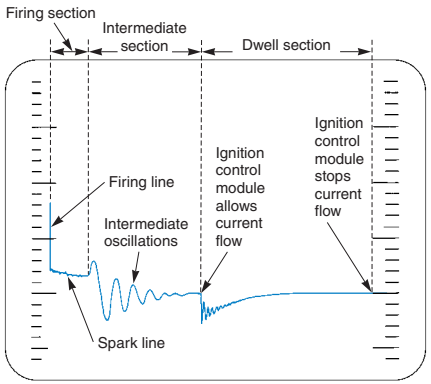


Figure 46-18. A secondary waveform for one cylinder. The firing line is voltage needed to fire the spark plug. The spark line is voltage needed to maintain the spark across the plug gap. Intermediate oscillations show the coil and condenser action. Dwell is the amount of time primary current flows through the ignition coil.

Secondary Scope Pattern

The ***secondary scope pattern*** shows the high voltages needed to fire the spark plugs. **Figure 46-18** illustrates the secondary pattern for one cylinder.

Secondary Firing Section. The secondary pattern starts on the left with the firing section. The ***firing section*** will pinpoint problems with the spark plugs, the plug wires, the distributor rotor, and the distributor cap, **Figure 46-18.**

The ***firing line*** is the tall spike or line representing the amount of voltage needed to cause the electric arc to jump across the spark plug gap. It is normally the peak voltage in the ignition system, **Figure 46-18.**

The ***spark line*** shows the voltage used to maintain the arc across the spark plug electrodes, **Figure 46-18.** Once the spark is started, less voltage is needed to maintain the arc. The spark line should be almost straight, clean, and about one-fourth as high as the firing line.

Secondary Intermediate Section. The secondary pattern's ***intermediate section,*** or ***coil oscillations section,*** shows voltage fluctuations after the spark plug stops firing. Typically, the voltage should swing up and down four times (four waves) at low engine speeds. This section of the pattern will indicate problems with the ignition coil or coil pack. See **Figure 46-18.**

The voltage oscillations will disappear at the end of the intermediate section as the ignition amplifier begins to conduct or the breaker points close.

Secondary Dwell Section. The secondary pattern's ***dwell section*** starts when the ignition module conducts primary current through the ignition coil. In a contact point system, it is the time when the points are closed. The ignition coil is building up a magnetic field during the dwell section.

The dwell section will indicate problems such as a faulty ignition module, burned contact points, or a leaking condenser. Contact point dwell (related to point gap) can be read by measuring the length of the dwell section along the bottom scale of the scope screen.

Tech Tip!
An electronic ignition can have different dwell periods from cylinder to cylinder. However, if the dwell varies in a contact point ignition, it indicates distributor wear or damage.

The scope pattern for an electronic ignition will vary from the pattern of a contact point ignition. The firing and intermediate sections are similar, but the dwell sections differ. Instead of mechanical contact points, an ignition module operates the ignition coil. The circuit design inside the module determines the shape of the dwell section. If you are not familiar with electronic ignition waveforms, they can be easily misinterpreted.

Scope Test Patterns

There are five scope test patterns commonly used by the technician when checking ignition system operation:

primary superimposed, secondary superimposed, parade (display), raster (stacked), and expanded display (cylinder select).

As you will learn, each of these patterns is capable of showing certain types of problems.

Primary Superimposed Pattern

The ***primary superimposed pattern*** shows the low voltages in the primary system—the ignition module or the condenser, coil primary windings, and points.

Superimposed means that the patterns for all the cylinders are placed on top of one another. This makes the trace line thicker than the single cylinder pattern discussed earlier.

Sometimes, an experienced technician will inspect the primary superimposed pattern before going to the more informative secondary pattern.

Secondary Superimposed Pattern

The ***secondary superimposed pattern*** places all the cylinder waveforms on top of each other, but it also shows the high voltages produced by the ignition coils. It is one of the most commonly used scope patterns. The superimposed secondary waveform allows you to quickly check the operating condition of all cylinders. Look at **Figure 46-19A.**

For example, if one spark plug is not firing properly, the waveform for that cylinder (spark plug) will not align with the others. The abnormal trace will stand out because the firing voltage is higher or lower than normal.

The secondary superimposed pattern is used to check for general problems in the ignition system. If one of the waveforms is out of place, the other scope patterns may be used to find exactly which component is causing the problem.

Parade Pattern

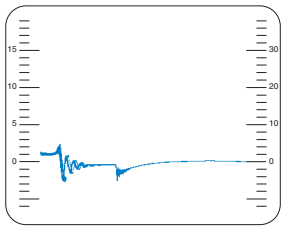
The ***parade pattern***, also called the ***display pattern,*** lines up the waveform for each cylinder side by side across the screen. The number one cylinder is on the left. The other cylinders are displayed in firing order going to the right, **Figure 46-19B.**

The parade pattern takes the superimposed waveforms and separates each along a horizontal axis. This makes the parade pattern useful for comparing firing voltages of each spark plug. If one or more firing lines are too tall or short, a problem is present in those cylinders.

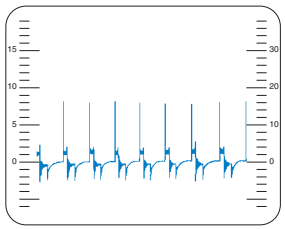
During normal operating condition, secondary voltages will vary from 5-12 kV for contact point ignitions and from 7-25 kV for electronic ignitions. The electronic ignition normally produces higher voltages because of the wider spark plug gaps needed to ignite lean fuel mixtures.

A *tall firing line* on the parade pattern indicates high resistance in the ignition secondary caused by an open spark plug wire, a wide spark plug gap, a burned distributor cap side terminal, or a burned secondary connection in a distributorless ignition. High resistance requires higher voltage output from the ignition coil.

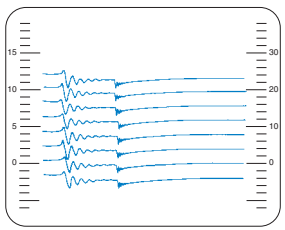
A *short firing line* indicates low resistance in the ignition secondary, which may be an indication of



A—Superimposed display has all patterns on top of each other. It checks that all patterns are uniform.



B—Parade display has cylinder patterns side by side in firing order. It is useful for comparing firing voltages. Number one cylinder is on left, with its firing line on the right.



C—Stacked or raster has all cylinders one above the other. It is useful for comparing duration of events. Number one is on bottom. Others are in firing order.

Figure 46-19. Three common scope test patterns. A—Superimposed. B—Parade pattern. C—Stacked or raster pattern. (FMC)

leaking spark plug wire insulation, oil-fouled spark plugs, carbon tracking on the distributor cap or coil pack, or similar problems. Not as much voltage would be needed.

Raster Pattern

In a ***raster pattern,*** or ***stacked pattern,*** the voltage waveforms are placed one above the other as shown in **Figure 46-19C.** The bottom waveform is the number one cylinder. The other cylinders are arranged in firing order from the bottom up.

The raster pattern is normally used to check timing or dwell variations between cylinders.

Expanded Display

Some oscilloscopes have a control that allows one cylinder waveform to be displayed above the parade pattern. This arrangement is called an ***expanded display,*** or ***cylinder select.*** If a problem is located in one trace, that trace can be expanded (enlarged and moved up on screen) for closer inspection.

Reading Oscilloscope Patterns

To read a scope pattern, inspect the waveform for abnormal shapes (high or low voltages, incorrect dwell or time periods).

Since there are so many variations of electronic ignition waveforms, refer to the scope operating manual or another reference. Locate an illustration of a good scope pattern for the particular ignition system and compare it to the test pattern.

Figure 46-20 shows electronic ignition waveforms from several manufacturers. They can be used as a guide when troubleshooting. **Figure 46-21** shows the true spark and the waste spark that occur when one ignition coil in a coil pack fires two spark plugs at once. **Figure 46-22** gives several faulty scope patterns.

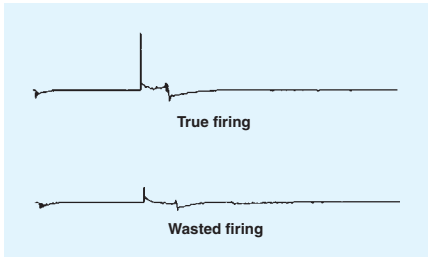


Figure 46-21. Note the differences between true firing (actual spark) and wasted firing (waste spark) when one coil fires two spark plugs at the same time. True firing starts the air-fuel mixture burning while the waste firing does nothing since the cylinder is on its exhaust stroke. (Snap-on Tool Corp.)

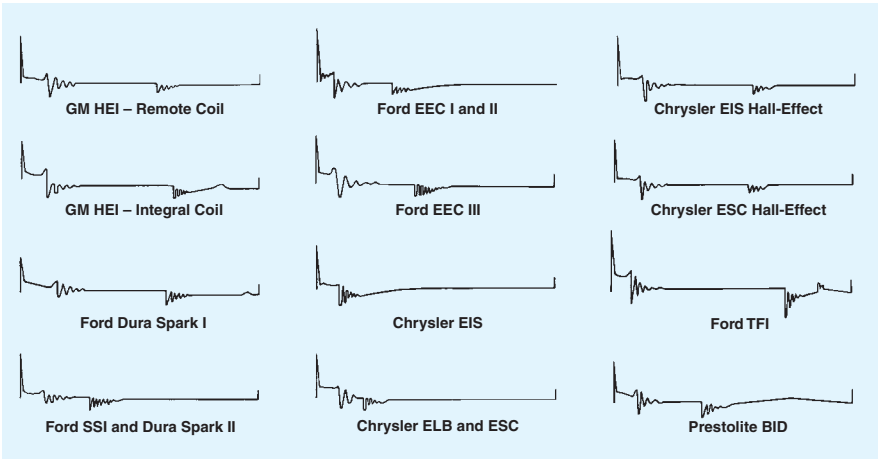
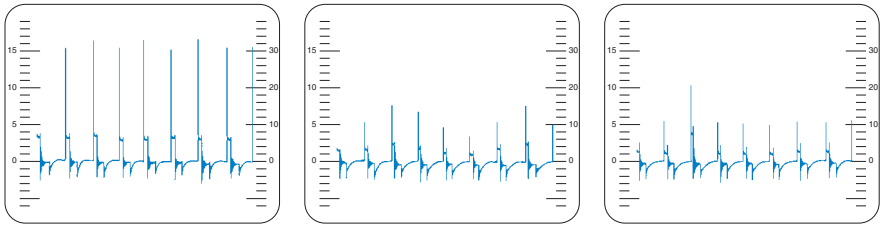


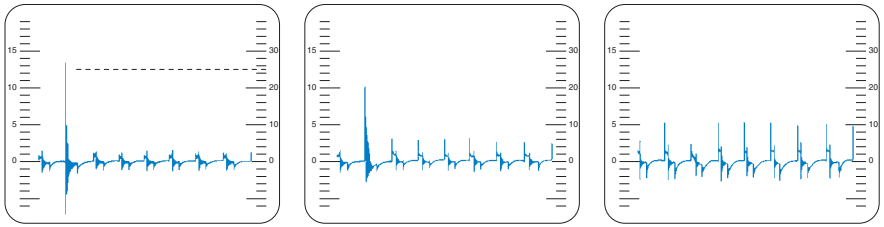
Figure 46-20. Study the differences in secondary waveforms from various auto manufacturers. (Snap-on Tool Corp.)



All firing lines fairly even but too high. Look for problems common to all cylinders: worn spark plug electrodes, excessive rotor gap, coil high-tension wire broken or not seated fully, late timing, excessively lean air/fuel mixture, or air leaks in intake manifold.

Uneven firing lines. Can be caused by worn electrodes, a cocked or worn distributor cap, fuel mixture variations, vacuum leaks, or uneven compression.

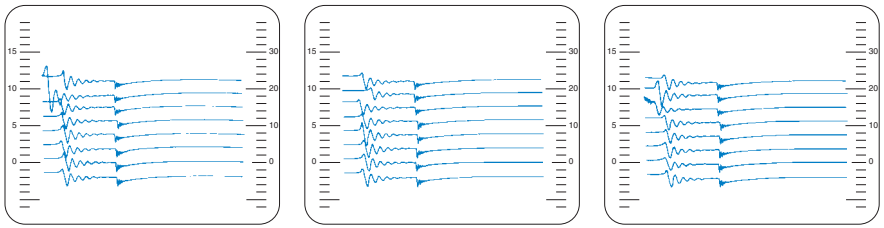
Consistently high firing line in one or more cylinders. Caused by a broken spark plug wire, a wide spark plug gap, or a vacuum leak.



Maximum available voltage during coil test should be within the manufacturer´s specifications. Disconnect plug wire to check maximum coil output.

With plug wire removed for coil output test, a short, intermittent, or missing lower spike indicates faulty insulation. This is usually caused by a defective spark plug wire, distributor cap, rotor, coil wire, or coil tower.

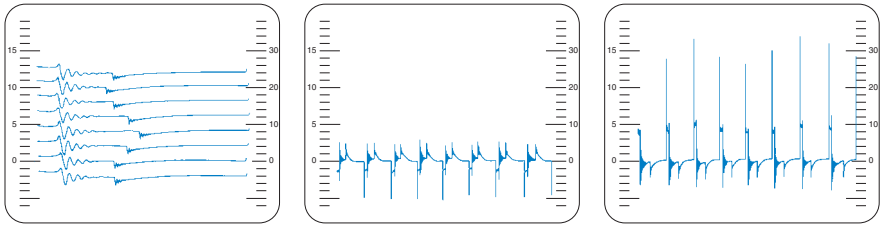
Consistently low firing line in one or more cylinders. Caused by fouled plug, shorted wire, low compression (valve not closing), or rich mixture.



No spark line. Caused by complete open in cable or connector.

Long spark line. Caused by a shorted spark plug or partially grounded plug wire.

Sloped spark line, usually with hash. Caused by fouled spark plug.



Poor vertical alignment of point-open spikes. Caused by worn or defective distributor shaft, bushings, cam lobes, or breaker plate.

Reversed coil polarity. The pattern is upside down. This problem is usually caused by someone accidentally connecting the primary leads to the coil backwards. The ignition will still work, but not as well.

Run the engine at about 1000 rpm. While watching firing lines on scope, snap throttle fully open, then quickly release it. Highest firing line peaks should not be more than 75% of coil output.

Figure 46-22. Examples of bad scope patterns. Study the shape of each trace and the problems that cause each waveform. (FMC)

Analyzing Square and Sine Wave Signals

When analyzing a square wave, there are several things you should check. They include:

- The ***base line*** is the reference line, or zero volts.
- The ***rising edge,*** or ***leading edge,*** is where the square wave goes from zero to high voltage.
- The ***on-time,*** or ***high-time,*** is the part where the square wave stays at maximum voltage.
- The ***trailing edge,*** or ***falling edge,*** is the drop in voltage back to zero.
- The ***off-time,*** or ***low-time,*** is where the square wave stays on the baseline.
- The ***amplitude,*** or ***peak-to-peak voltage,*** of a square wave is determined by the horizontal distance from the baseline to the high-time.

You can inspect these sections of the waveform to determine if there is a problem. Some common problems that can affect a square wave include:

- Low or high resistance in the circuit or its components.
- Faulty electronic circuit.
- Circuit contaminated by moisture.

When analyzing sine waves, check the following:

- Analog peak-to-peak voltage—Is the waveform voltage strong from top to bottom?
- Analog wave shape—Is the trace normal for a known good component?
- Analog wave frequency—Is the distance between waves normal?
- Analog wave smoothness—Is there unwanted hair or static on sine wave?

Computer System Scope Tests

An oscilloscope can be used to help you find computer system problems. When the scan tool does not find anything and you still have performance problems, you may need to check sensor and ECM signals with a scope.

Distributor Pickup Coil Scope Testing

An oscilloscope can also be used to check the output signal of a distributor pickup coil. It will not only measure voltage, but it will also show the shape of the signal leaving the pickup coil.

Magnetic Sensor Testing

A ***magnetic sensor test*** is done by measuring the output voltage from the sensor with the engine cranking. With a magnetic sensor, connect the scope primary leads to the pickup coil. Set the selector to primary and the primary height control to 40V. Adjust the pattern length to minimum.

With the engine cranking, an ac (alternating current) signal about 1.5V peak-to-peak should be generated, **Figure 46-23.**

Hall-Effect Sensor Testing

A ***Hall-effect sensor test*** is best done by checking the sensor's output waveform with an oscilloscope. Without disconnecting the circuit reference voltage, probe the output wire at the sensor connector. The service manual will give pin numbers for probing. See **Figure 46-24A.**

A Hall-effect sensor waveform should switch rapidly, have vertical sides, and have the specified voltage output (typically about 4–5 volts peak-to-peak). The top of the square wave should reach reference voltage and the bottom should almost reach ground, or zero. Signal frequency should change with engine cranking speed or engine rpm. See **Figure 46-24B.**

Hall-effect pickups can be found in distributors and some crankshaft position sensors. Since specifications vary for Hall-effect sensors, refer to the service manual for that vehicle.

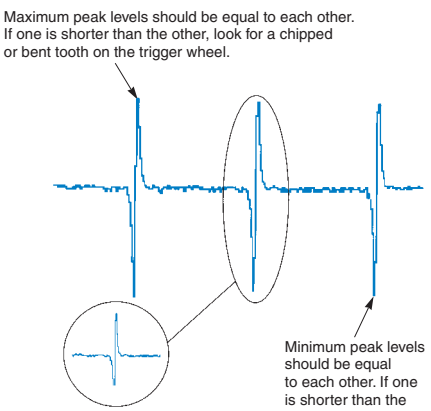

Maximum peak levels should be equal to each other. If one is shorter than the other, look for a chipped or bent tooth on the trigger wheel.
The waveform signature is created from the unique shape of the trigger wheel tooth, passing the pickup coil.
Minimum peak levels should be equal to each other. If one is shorter than the other, look for a chipped or bent tooth on the trigger wheel.

Figure 46-23. Typical waveform from a magnetic distributor pickup. (Fluke)

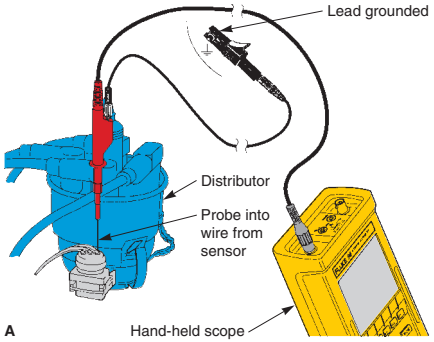

Lead grounded
Distributor
Probe into wire from sensor
Hand-held scope
A
The upper horizontal lines should reach reference voltage
Voltage transitions should be straight and vertical
Peak-to-peak voltages should equal reference voltage
The lower horizontal lines should almost reach ground
B

Figure 46-24. A—This scope is being used to check the signal from a Hall-effect sensor. B—Hall-effect sensor signal. The frequency of the signal should increase as engine speed increases. (Fluke)

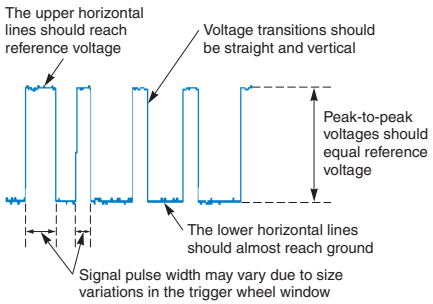

The upper horizontal lines should reach reference voltage
Voltage transitions should be straight and vertical
Peak-to-peak voltages should equal reference voltage
The lower horizontal lines should almost reach ground
Signal pulse width may vary due to size variations in the trigger wheel window

Figure 46-25. Typical waveform generated by an optical sensor. If the shutter blade widths vary, the pulse width will also vary. (Fluke)

Optical Sensor Testing

An optical sensor can also be tested with an oscilloscope. You can probe the output wires from the sensor and compare the waveform to specifications.

An ***optical pickup test*** measures the output generated by the photo diodes as they are energized by the LEDs. It is also easily done with a hand-held scope probing into the sensor's electrical connector. Again, refer to the service manual to find the connector pin numbers for the optical pickup's output wire. Optical sensors are used in a few distributor designs and are never used in crankshaft sensors.

An optical sensor's waveform should have straight sides and adequate voltage output. The upper horizontal line on the waveform should almost reach reference voltage. The bottom horizontal line should almost reach ground, or zero. See **Figure 46-25.**

Remember that optical sensors are susceptible to dirt. An oil mist or a film of dirt can prevent light transfer from the LEDs to the photo diodes. Again, refer to the manufacturer's service literature for specific information.

Crankshaft Position Sensor Testing

Figure 46-26A shows how to use a hand-held scope to test a crankshaft position sensor. You can use the needle probe on the scope lead to check for an output signal without disconnecting wires. This scope will show both ac output and a trace for voltage signal variations. Note that this testing method would also work on engine block–mounted magnetic crankshaft position sensors.

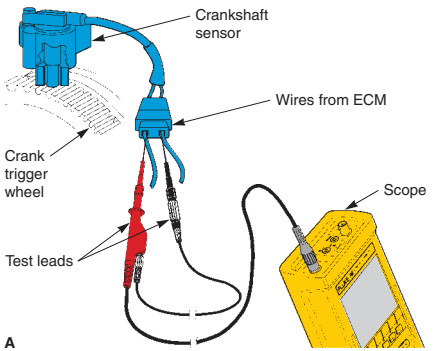
Tech Tip!
Some electrical connectors are sealed and do not allow easy probing. You may need to install a test connector or jumper wires between the two halves of the connector to probe sensor voltages.

When reading the sensor waveform, make sure the peak voltage levels are equal to each other. If one is short or missing, inspect the trigger wheel for a broken tooth. Peak-to-peak voltage levels should be within specifications. See **Figure 46-26B.**

As with any sensor, reference voltages, wiring, and other criteria will vary. If in doubt, always refer to the service manual for the vehicle being tested to get accurate electrical values.

Throttle Position Sensor Testing

To scope test a throttle position sensor (TPS), connect the test leads to the sensor output wire and to ground. Voltage should still be fed to the sensor from the ECM. Move the throttle open and closed. The TPS waveform should show a smooth curve, without any spikes. See **Figure 46-27.**



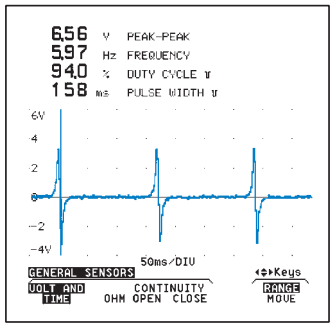


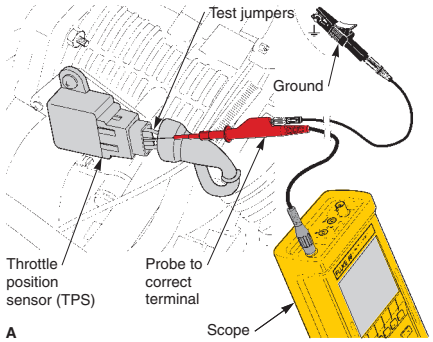
Figure 46-26. Scope testing crankshaft position sensors is similar to testing magnetic distributor sensors. A—Since crankshaft sensors generate their own voltage signal, connect scope to terminals as specified. B—Note the resulting display. Compare the waveform to the service manual description.

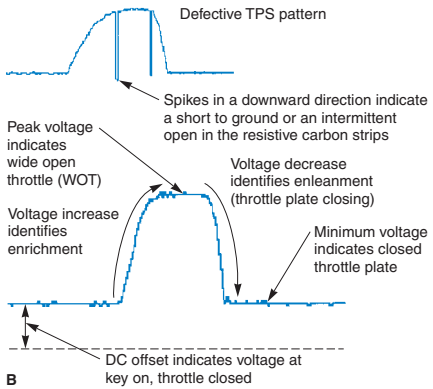
Manifold Absolute Pressure Sensor Testing

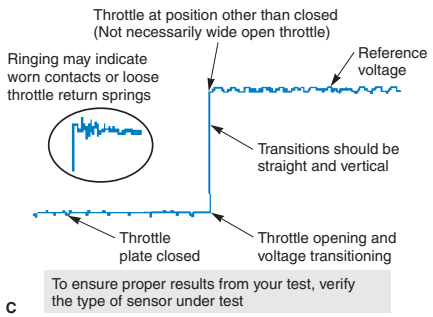
A scope can also be used to test the operation of both analog and digital manifold absolute pressure sensors. Accelerate the engine and note the changes in airflow signals going to the ECM. Compare the amplitude and shape of the waveform to known good patterns. This is shown in **Figure 46-28.**

Mass Airflow Sensor Testing

To test analog or digital mass airflow sensors using a scope, probe the connector as recommended in the service manual. Compare your scope readings to factory specifications and known good readings. See **Figure 46-29.**

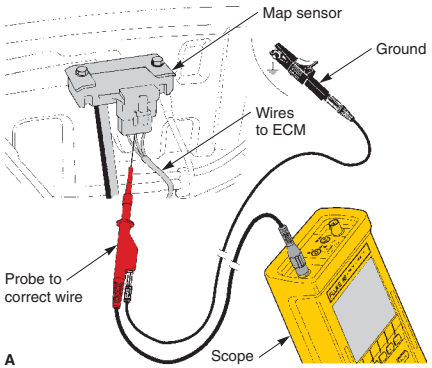


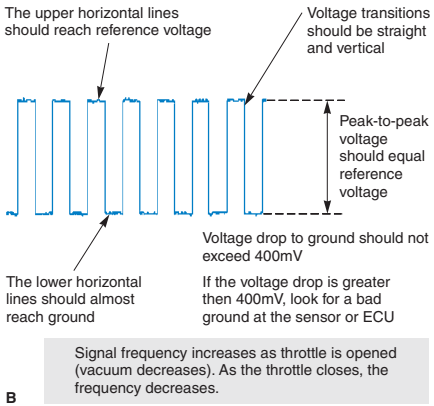

Defective TPS pattern
Spikes in a downward direction indicate a short to ground or an intermittent open in the resistive carbon strips
Peak voltage indicates wide open throttle (WOT)
Voltage decrease identifies enleanment (throttle plate closing)
Voltage increase identifies enrichment
Minimum voltage indicates closed throttle plate
DC offset indicates voltage at key on, throttle closed
B


Throttle at position other than closed (Not necessarily wide open throttle)
Ringing may indicate worn contacts or loose throttle return springs
Reference voltage
Transitions should be straight and vertical
Throttle plate closed
Throttle opening and voltage transitioning
C

To ensure proper results from your test, verify the type of sensor under test

Figure 46-27. Throttle position sensor can also be checked with a scope. A—Probe through wires or use jumpers so power can be connected to sensor. B—Potentiometer, or variable-resistor, TPS should produce smooth curve as throttle is moved open and closed. Spikes indicate sensor problem. C—Switching-type TPS should produce good square wave without ringing. (Fluke)




The upper horizontal lines should reach reference voltage
Voltage transitions should be straight and vertical
Peak-to-peak voltage should equal reference voltage
Voltage drop to ground should not exceed 400mV
The lower horizontal lines should almost reach ground
If the voltage drop is greater then 400mV, look for a bad ground at the sensor or ECU
Signal frequency increases as throttle is opened (vacuum decreases). As the throttle closes, the frequency decreases.
B

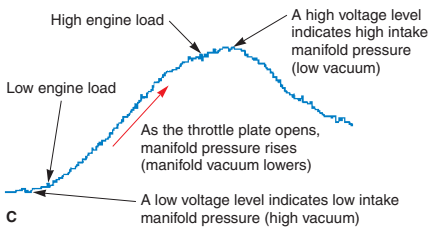
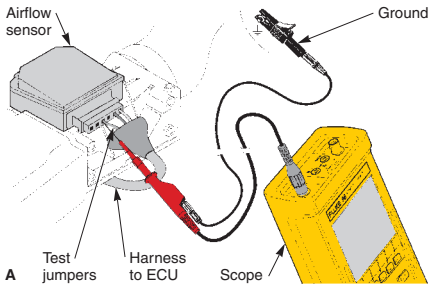
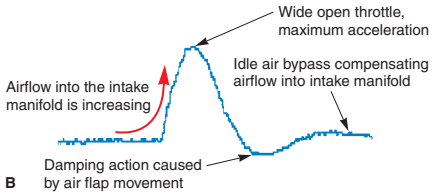

High engine load
A high voltage level indicates high intake manifold pressure (low vacuum)
Low engine load
As the throttle plate opens, manifold pressure rises (manifold vacuum lowers)
A low voltage level indicates low intake manifold pressure (high vacuum)
C

Figure 46-28. Manifold absolute pressure sensor can also be checked with scope. A—Here scope is probing through connector to test MAP sensor. Other lead is grounded. B—Signal frequency should increase with engine speed with digital MAP. C—Amplitude should increase with engine speed with analog MAP. (Fluke)




Wide open throttle, maximum acceleration
Idle air bypass compensating airflow into intake manifold
Airflow into the intake manifold is increasing
Damping action caused by air flap movement
B

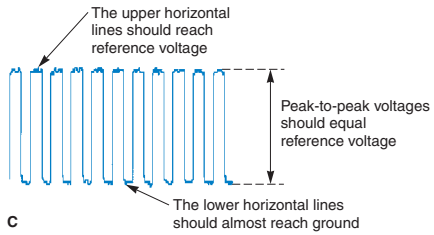
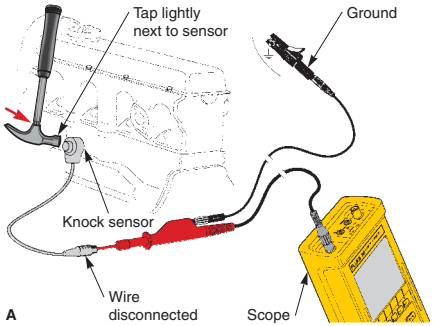

The upper horizontal lines should reach reference voltage
Peak-to-peak voltages should equal reference voltage
The lower horizontal lines should almost reach ground
C

Figure 46-29. Note basic method for testing analog and digital airflow sensors. A—Jumpers are being used to allow power to remain connected to sensor. Probe service manual recommended pins or wires. B—As flow increases, analog airflow meter should produce more voltage. C—With digital airflow meter, signal frequency usually increases with engine speed and airflow. (Fluke)

Knock Sensor Testing

To test a knock sensor with a scope, connect the scope test leads to the sensor. Then tap on the engine next to the sensor with a small hammer or a wrench. See **Figure 46-30A.** This should make the sensor produce a signal that is similar to the one shown in **Figure 46-30B.**

Another way to check a knock sensor and the ECM is to measure ignition timing while tapping on the engine next to the sensor. The ECM should retard ignition timing when you tap on the engine.



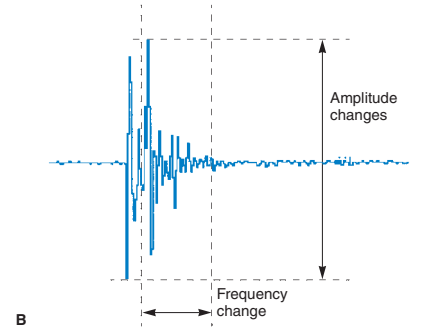


Figure 46-30. Knock sensor signal can also be analyzed with scope. A—Connect scope lead to knock sensor and other lead to ground. Tap on engine with small hammer or wrench to produce output signal. B—Knock sensor should produce normal frequency and amplitude signal when engine is tapped on. (Fluke)

Alternator Diode Testing

Most analyzers are capable of checking alternator diode condition. The scope will display the alternator's voltage output. If the alternator diodes are good, the pattern should be wavy but almost even. This was detailed in Chapter 34, *Charging System Diagnosis, Testing, and Repair.*

Electronic Fuel Injector Testing

Oscilloscopes can also be used to check injector operation in an electronic fuel injection system. Refer to equipment and service manual instructions for details. **Figure 46-31** shows typical waveforms for good and defective fuel injectors.

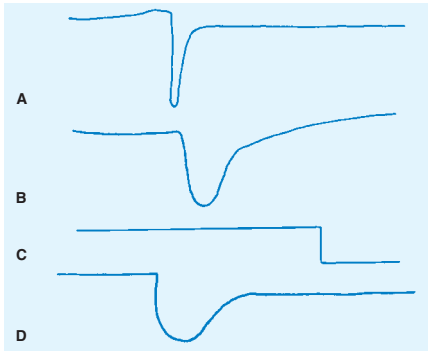


Figure 46-31. These are waveforms for electronic injectors. A—Normal injector pattern. B—Stuck injector. C—Open injector. D—Partially shorted injector. (Snap-on Tool Corp.)

Oxygen Sensor Testing

An oscilloscope can be used to check the signal produced by an oxygen sensor. Oxygen sensor testing and service is covered in detail in Chapter 44, *Emission Control System Testing, Service, and Repair.*

ECM Scope Testing

A scope can be used to check the output pulses leaving an electronic control module. You can measure and observe the pulses going to fuel injectors, solenoids, and servo motors. You can also check the reference voltage being sent to sensors, **Figure 46-32.**

Since ECM testing varies and is complex, always refer to the service manual for detailed instructions. You must compare your test waveform or voltage to known correct values. If the ECM fails to produce a good pulse or reference voltage, it should be replaced.

Note!
For more information on ECM service, refer to the index. This subject is covered in several other chapters.

Flight Record Test

A ***flight record test*** stores the sensor or actuator waveform in the scope's memory when a problem occurs. For example, when trying to check an intermittent problem, connect the hand-held scope to the sensor and test drive the vehicle. When the problem occurs, press the storage button on the scope. The scope will then store a picture of the sensor output for analysis, **Figure 46-33.**

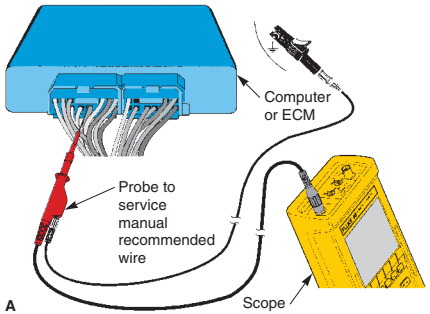


Figure 46-32. A—A scope will also check reference voltage going to sensors and the control pulses from the ECM to the actuators. Compare readings and waveforms to service manual specifications. B—Reference voltages should meet specifications and the waveforms should reflect smooth dc voltage. (Fluke)

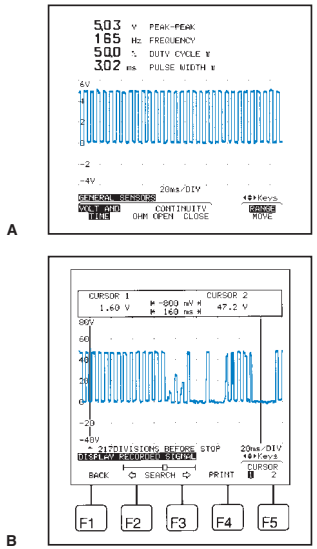


Figure 46-33. The flight record is a feature on some small hand-held scopes. Connect to a suspect sensor using long test leads and place the scope on seat during test drive. A—Normal, consistent signals from magnetic sensor. B—When the problem occurs, the scope will store a picture of the sensor signals. Note how each signal varies, possibly from intermittent open sensor coil windings or loose mounting. (Fluke)

Engine Analyzer (Computer Analyzer)

An ***engine analyzer,*** also called a ***vehicle analyzer*** or computer analyzer, consists of a group of test instruments that includes a scope, a tach-dwell meter, a VOM, an exhaust gas analyzer, and, sometimes, a scan tool. These tools are mounted in a large, roll-around cabinet. The operation of each instrument is often controlled by a computer that interfaces all the testing devices. See **Figure 46-34.**

When connected to the vehicle, the analyzer will help you check the condition of the engine and its support systems. An engine analyzer will help find problems when a scan tool does not show a trouble code or an out-of-parameter operating value.

For example, if an engine misfire is being diagnosed, the analyzer will help find which parts are defective. It will pinpoint fouled spark plugs, open plug wires, rich or lean fuel mixtures, inoperative fuel injectors, and other problems, even before removing and inspecting parts.

Figure 46-34. This technician has test driven a vehicle with a hand-held scan tool connected to a flight recorder tester. At the shop, the data collected can be fed into a computerized analyzer for further evaluation. This is useful on difficult-to-find problems. (OTC Div. of SPX Corp.)

Modems

Some analyzers can transmit data over telephone lines for comparison to information stored in a larger mainframe computer by using a modem. A ***modem*** is an electronic device that allows computer data to be sent and received over telephone lines.

Data can be sent back and forth between modems. This allows the technician to access information that can be used to troubleshoot difficult problems. Most dealerships have modem-equipped computer analyzers. The analyzer is plugged into the vehicle's data link connector and the information is sent by modem to the mainframe computer.

A ***mainframe computer*** is a very large computer that can store tremendous amounts of data. It can also do multiple tasks or transfer information to several computer analyzers at the same time.

The auto or equipment manufacturer's mainframe computer may contain information about common problems. Steps for finding problems, specific voltages, and other electrical values for each model may also be stored in the mainframe's memory.

Engine Analyzer Differences

There are a number of different makes of analyzers on the market. The controls and meter faces may be organized differently, but the basic test equipment and operation of each are almost the same. See **Figure 46-35.** Most analyzers will check:

Figure 46-35. An analyzer can perform different tests and measurements. It is like having a multimeter, tach-dwell, exhaust analyzer, timing light, and other testers connected at once for problem evaluation.

- Battery, charging, and starting systems.
- Ignition system.
- Engine condition.
- Fuel system.
- Emission control systems.
- Sensor and ECM signals.

Analyzer Test Equipment

Typically, an analyzer will contain several pieces of test equipment, including:

- *Oscilloscope*—high-speed meter that uses a liquid crystal display or a television picture tube.
- *Voltmeter, ammeter, and ohmmeter*—meters used to measure electrical values.
- *Tachometer*—meter used to measure engine speed in rpms. It is commonly used when adjusting fuel injection, ignition timing, and idle speed.
- *Dwell meter*—instrument that measures ignition module or contact point conduction time in degrees of distributor rotation. It will detect point misadjustment and other problems.
- *Timing light*—strobe light for ignition timing adjustment. Most analyzer timing lights have a degree meter for measuring distributor advance.
- *Vacuum gauge*—gauge used to measure vacuum when checking the operation of the engine operation and various vacuum-operated devices.
- *Vacuum pump*—pump capable of producing a supply vacuum for operating and testing vacuum devices.
- *Cylinder power balance tester*—unit for electrically shorting out one or more fuel injectors or spark plugs. It will determine if a cylinder is firing properly and producing power.
- *Exhaust gas analyzer*—measures the chemical content and amount of pollution in the vehicle's exhaust.
- *Scan tool*—often incorporated into analyzers for retrieving trouble codes and circuit operating values.
- *Digital display*—displays operating values for various components in alpha-numeric form. Modern analyzers display readings of various test values—engine rpm, charging system voltage, exhaust gas content, etc. See **Figure 46-36.**
- *Printer*—prints information about ignition timing, dwell, engine speed, emission levels, and other values on paper. If repairs are needed, the technician can show the customer the improper readings on the printout. If the vehicle is in good condition, the printout can serve as a record if later repairs are needed. See **Figure 46-37.**

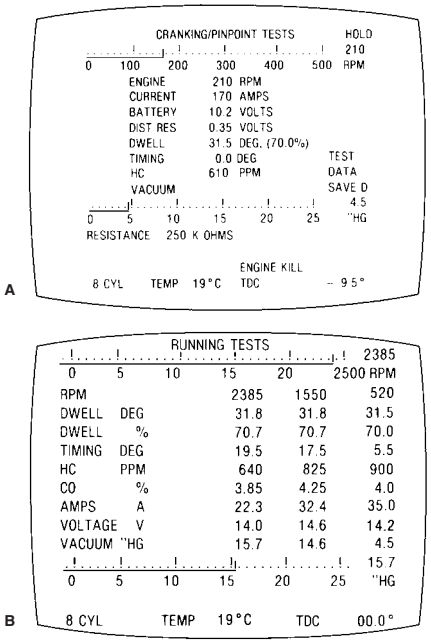


Figure 46-36. Many modern analyzers are equipped with a digital display or extra screen. A—Digital display for cranking tests. B—Digital display for running tests. (Snap-on Tool Corp.)

Figure 46-37. A printer will type or print analyzer test results.

Figure 46-38. Most late model analyzers will give detailed instructions for connecting the various leads to the vehicle and for doing each test. This simplifies analyzer operation considerably. (Snap-on Tool Corp.)

Analyzer Connections

Analyzer connections differ with each type and model. Nevertheless, most have the same general test connections. Modern analyzers will give you directions for connecting the test leads to the vehicle, **Figure 46-38.** If not, test leads should be connected as described in the user's manual. Special leads and hoses may be provided for measuring starting current, charging voltage, engine vacuum, fuel pump pressure, sensor signals, and exhaust gas content. These leads are generally connected in the same manner as those covered in other chapters.

Figure 46-39 shows how to connect an analyzer to conventional and unitized ignition coils. An adapter may be needed to connect the analyzer to a distributorless ignition system, **Figure 46-40A.** You must install secondary jumper wires on some direct ignition systems so the inductive test leads can be clamped around them to read voltages, **Figure 46-40B.**

Using an Analyzer

To use an analyzer, plug the electrical cord into a wall outlet. Set the controls and connect the test leads to the vehicle. If needed, read the operating manual for the analyzer.

Caution!
Before starting the engine, make sure all leads are away from hot or moving parts. The analyzer leads are very expensive and can be easily damaged by contact with a hot exhaust manifold or a spinning fan blade or pulley. See **Figure 46-41.**

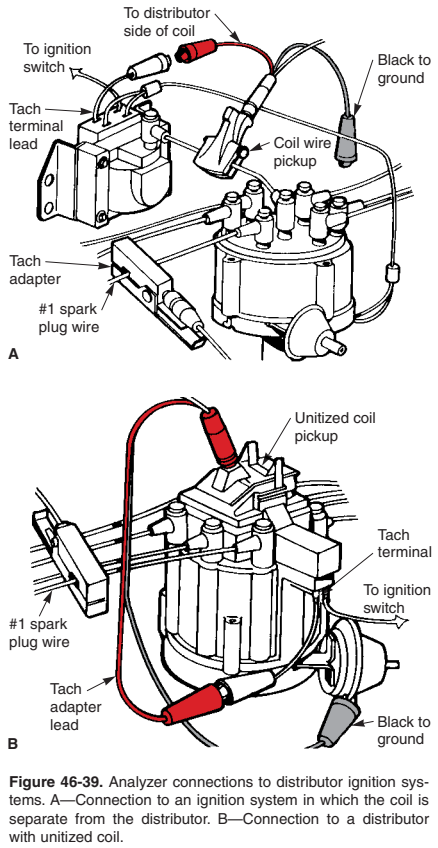


Figure 46-39. Analyzer connections to distributor ignition systems. A—Connection to an ignition system in which the coil is separate from the distributor. B—Connection to a distributor with unitized coil.

Set the parking brake and start the engine. Many analyzer manufacturers recommend increasing engine idle speed to around 1500 rpm during scope tests.

Ignition Coil Output Test

A scope ***ignition coil output test*** measures the maximum available voltage produced by the ignition coil. A spark plug requires only about 5–20 kV for operation. However, the ignition coil should have a higher reserve voltage. Without this extra voltage, the spark plugs could misfire under load or at high engine speeds when voltage requirements are greater.

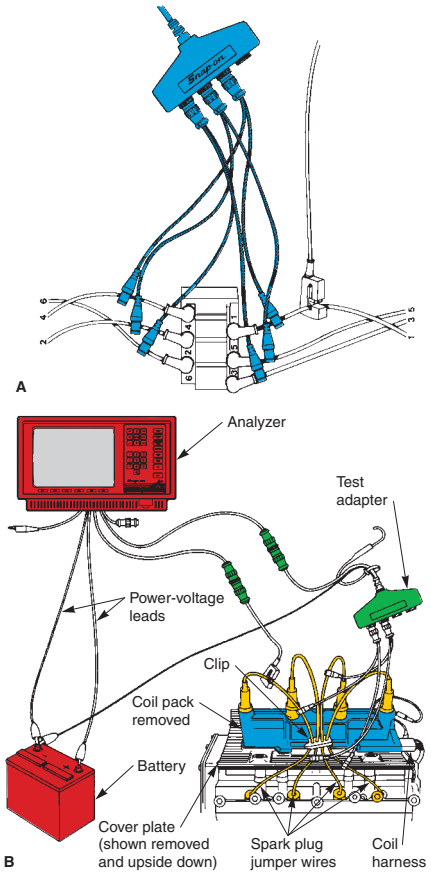


Figure 46-40. This is operating manual illustration for connecting an analyzer to distributorless and integrated direct ignition systems. A—Separate inductive leads are needed for each wire on this distributorless ignition system. B—Note jumper spark plug wires between coil pack and spark plugs. (Snap-on Tool Corp.)

To perform the coil output test, set the analyzer controls and display to the highest kV range. Run the engine at 1000–1500 rpm. Using insulated pliers, disconnect a spark plug wire. Hold the end of the wire away from ground while watching the scope screen.

Figure 46-41. When connecting an analyzer to a vehicle, keep all cables away from hot or moving parts. Test cables are very expensive to replace.

Tech Tip!
With a coil pack, you must test each coil's output voltage separately. Just because one coil passed its tests does not mean the others will. By using the coil pack firing order and the secondary pattern, you can tell which coil should be tested.

With the spark plug wire removed, a tall firing line should stand out from the others. Look over to the scope scale on the side of the screen. Read the voltage even with the top of the spike. This value should equal the capacity of the ignition coil.

Caution!
A few electronic ignitions may be damaged by disconnecting spark plug wires while the engine is running. Be sure to check manufacturer's directions.

With older electronic ignitions, coil output voltage should range between 30,000–45,000 volts. However, some electronic ignition coils are able to produce up to 100,000 volts.

Warning!
Even though ignition coil or coil pack current is too low to normally cause electrocution, the high voltage could injure you or cause a potentially deadly heart attack.

If the ignition coil voltage is below specifications, do not condemn the coil until completing further tests. Low coil output could be due to low primary supply voltage, leaking secondary wires, or similar problems. Eliminate these as sources of the problem before replacing the ignition coil.

Load Test

A ***load test,*** or ***acceleration test,*** measures the spark plug firing voltages when engine speed is rapidly increased. When an engine is accelerated, higher voltage is needed to fire the spark plugs. While a defective component may produce a normal scope pattern at idle, it may not operate properly under load.

To perform a load test, set the scope on parade and idle the engine between 1000 and 1200 rpm. While watching the firing lines on the scope, quickly open the injection throttle valve (or carburetor throttle plate) and release it. The firing voltage should increase, but it must not exceed certain limits.

The highest firing line should not be more than 75% of actual coil output. Typically, voltage should *not* exceed 15 kV in a contact point ignition or 20 kV in an electronic ignition. The upward movement of the firing lines during the load test should be the same. If any of the firing lines are high or low, a defect is present.

Cylinder Balance Test

A ***cylinder balance test,*** also called a ***power balance test,*** measures the power output from each of the engine's cylinders. As each cylinder is shorted, the tachometer should indicate an rpm drop. During a cylinder balance test, all cylinders should have the same percentage of rpm drop (within 5%). If a shorted cylinder does not produce an adequate amount of rpm drop, the cylinder is not firing properly. Study **Figure 46-42.**

Caution!
Never short a cylinder in a vehicle with a catalytic converter for more than 15 seconds; converter damage could result.

If the rpm drop in one or more cylinders is below normal, a problem common to those cylinders is indicated. The cylinders could have low compression (burned valve, blown head gasket, or worn piston rings), a lean mixture (vacuum leak, faulty fuel injector, or computer malfunction), or other problems.

Cranking Balance Test

A ***cranking balance test*** is done to check the engine's mechanical condition. It can be used to isolate a cylinder with low compression due to a burned valve, worn piston rings, or other problems. The analyzer will show how much current is drawn by the starter motor as each cylinder goes through its compression stroke. High current draw means high compression stroke pressure. Low current draw (low display line) means that cylinder has low compression. Look at **Figure 46-43.**

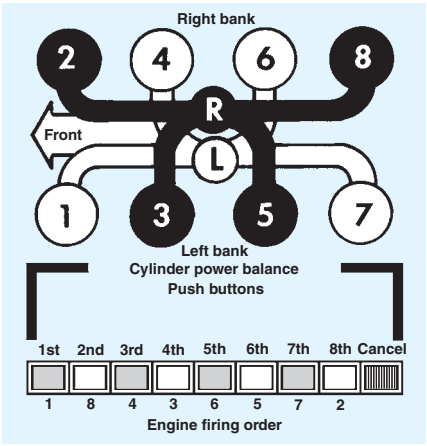


Figure 46-42. A cylinder balance test is done by pressing buttons on analyzer control panel. Each button will short and disable one cylinder. If the engine rpm does not drop sufficiently, that cylinder is not producing enough power. Note how each button corresponds to the firing order. A cylinder balance test will find any engine cylinder that is not producing power. Some analyzers will short each cylinder automatically and keep a record of the results.

Other Analyzer Tests

An analyzer is usually capable of performing other tests besides those discussed in this chapter. These include starter cranking amps, charging voltage, and exhaust gas analysis. Such tests are almost identical to those done with the individual instruments explained in other chapters.

Duff's Garage

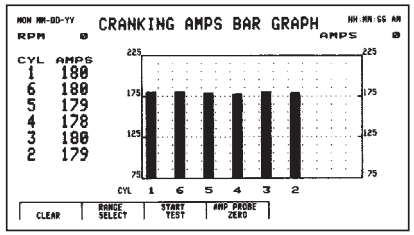
Problem: Mr. Farnsworth brings his 1999 Sierra pickup truck into the shop with an elusive problem. When asked to describe the problem, he says that the engine runs fine but loses all power after about an hour of highway driving. After the vehicle sits for about 20 minutes, it starts and runs again. Mr. Farnsworth says he has taken his truck to four different shops and none have been able to fix the problem.

Diagnosis: Duff checks for trouble codes and finds none. He also checks for obvious problems but finds nothing. Since the vehicle must be driven for an hour before engine stops running, Duff suspects that engine heat may be related to the problem, especially since the ECM is located in the engine compartment on this vehicle. He passes the job along to one of the shop's master automobile technicians.

The technician decides to begin his diagnosis by heating the ECM to normal operating temperature to determine whether it is causing the problem. He starts the engine and lets it idle. To ensure that he does not damage the ECM by overheating it, he places the probe of a digital thermometer on the ECM case. Next, he uses a heat gun to warm the ECM. When the ECM reaches 200° F, the engine stalls. The technician attempts to restart the vehicle without success.

Repair: The technician installs a new ECU and takes the car for a test drive. The vehicle operates properly. Back at the shop, the technician checks the ECM temperature with the digital thermometer. The ECM temperature is 210° F and the car is functioning normally. The test drive and diagnostic time are added to customer's bill and the car is released to the owner.

A



B

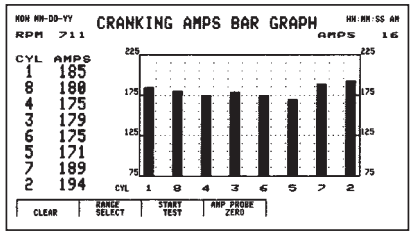


Figure 46-43. Cranking balance tests are used to check general engine compression. If any cylinder does not load the starter motor as much as the others, it has low compression pressure and a possible leak. A—All bar graphs are at the same height, so all cylinders have same compression. B—The number 5 cylinder has a low bar graph indicating less compression pressure. (Snap-on Tool Corp.)

Summary

- Strategy-based diagnostics involves using a consistent, logical procedure to narrow down possible problem sources.
- A vacuum gauge measures negative air pressure produced by the engine, fuel pump, vacuum pump, and other components.
- A pressure gauge measures positive pressure produced by the engine, turbocharger, fuel pump, or other device.
- A diesel injection tester is a set of pressure gauges and valves for measuring system pressure.
- A glow plug test harness can be used for checking a diesel engine rough idle problem.
- Scan tool datastream values are "live" electrical values measured with the vehicle running or driving.
- A breakout box allows you to pinpoint test electrical values at specific pins on the ECM or in the computer system.
- Electromagnetic interference results from induced voltage into wires and can cause a computer to malfunction.
- Scope voltage is shown on the scope screen along the vertical (up-and-down) axis or scale.
- Scope time may be given on the scope screen on the horizontal scale in degrees, milliseconds, or duty cycle.
- A primary pattern shows the low voltage or primary voltage changes in an ignition system.
- The secondary scope pattern shows the actual high voltages needed to fire the spark plugs.
- The term superimposed means that all the cylinder waveforms are placed one on top of the other.
- The parade pattern, also called the display pattern, lines up the waveform for each cylinder end-to-end across the screen.
- A magnetic sensor scope test is done by measuring the output voltage from the sensor with the engine cranking.
- Most electrical connectors are sealed and do not allow easy probing. You may need to install a test connector or jumper wires between the two halves of the connector to probe sensor voltages.
- An oscilloscope can be used to check the output pulses leaving an ECM or ignition module.
- A flight record test stores the sensor waveform in the scope memory when a problem occurs.
- An engine analyzer, also called a vehicle analyzer, consists of a group of test instruments including an oscilloscope, tach-dwell, VOM, exhaust gas analyzer, and sometimes a scan tool.
- A modem allows a shop-owned analyzer to communicate over telephone lines with a larger mainframe computer.
- An analyzer displays operating values for various components in number form.
- An ignition coil output test measures the maximum available voltage produced by the ignition coil.
- A load or acceleration test measures the firing voltage of the spark plugs when engine speed is rapidly increased.

Important Terms

Strategy-based diagnostics
Vacuum gauge
Pressure gauge
Vacuum-pressure gauge
Hand vacuum pump
Diesel injection tester
Glow plug test harness
Snap-shot
Scan tool datastream values
Breakout box
Electromagnetic interference (EMI)
Digital pyrometer
Dynamometer
Oscilloscope
Scope screen
Trace
Scope time
Scope sweep rate
Primary scope pattern
Secondary scope pattern
Firing section
Firing line
Spark line
Intermediate section
Coil oscillations section
Dwell section
Primary superimposed pattern
Secondary superimposed pattern
Parade pattern
Display pattern
Raster pattern
Stacked pattern
Expanded display
Cylinder select
Base line
Rising edge
Leading edge
On-time
High-time
Trailing edge
Falling edge
Off-time
Low-time
Amplitude
Peak-to-peak voltage
Flight record test
Engine analyzer
Vehicle analyzer
Modem
Mainframe computer
Ignition coil output test
Load test
Acceleration test
Cylinder balance test
Power balance test
Cranking balance test

Review Questions—Chapter 46

Please do not write in this text. Place your answers on a separate sheet of paper.

1. Define strategy-based diagnostics.
2. A vacuum gauge measures _____ air pressure.
3. A scan tool _____ _____ is a record of the operating parameters present at the moment a problem occurs.
4. Electromagnetic interference can be caused by _____.
   (A) loose wires
   (B) unshielded secondary wires
   (C) aftermarket accessories
   (D) All of the above.
5. A(n) _____ is one of the last tools used when diagnosing computer system problems.
6. On the scope screen, _____ is given on the vertical scale and _____ is given on the horizontal scale.
7. One kV equals _____.
   (A) 00 volts
   (B) 1000 volts
   (C) 10,000 volts
   (D) None of the above.
8. If a scope waveform is higher or taller than normal, this indicates a higher-than-normal _____.
9. The _____ scope pattern shows the actual voltages needed to fire the spark plugs.
10. Sketch and explain the three major parts of a scope secondary waveform.
11. How do you read a scope pattern?
12. Electronic ignition system waveforms will vary depending on the make and model of vehicle. True or False?
13. When analyzing a square wave, what six things should be checked?
14. Summarize how you use a scope to test computer system sensors.
15. With the engine cranking, a magnetic sensor should commonly produce:
    (A) 5 volts peak-to-peak.
    (B) 0.5 volts peak-to-peak.
    (C) 1.5 volts peak-to-peak.
    (D) 15 volts peak-to-peak.
16. How do you scope test a Hall-effect sensor?
17. Which of the following is commonly used as part of an analyzer?
    (A) Tach-dwell.
    (B) Oscilloscope.
    (C) Multimeter.
    (D) All of the above.
18. What is a scope digital display?
19. Most analyzers recommend that engine idle speed be increased to about _____ rpm during scope tests.
20. Which of the following tests measures the power output from each of the engine's cylinders?
    (A) Load test.
    (B) Cylinder balance test.
    (C) Ignition coil output test.
    (D) EFI injector test.

ASE-Type Questions

1. Technician A says that strategy-based diagnostics involves using a logical procedure to narrow down possible problem sources. Technician B says that advanced diagnostic techniques are used when conventional tests fail to pinpoint a problem. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
2. Technician A says computer terminal values can be measured with a low-impedance meter. Technician B says computer terminal values should be measured with a digital VOM. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
3. A scan tool has the capability to perform each of the following tasks except:
   (A) display datastream values.
   (B) capture a snap shot of operating parameters.
   (C) measure exhaust emissions.
   (D) switch actuators on and off.

4. Technician A says an oscilloscope's primary pattern represents the high-voltage changes in an engine's ignition system. Technician B says an oscilloscope's primary pattern represents the low-voltage changes in an engine's ignition system. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
5. An oscilloscope is connected to an automobile engine to check ignition system operation. The scope's primary pattern indicates a malfunction in this section of the ignition system. Technician A says this malfunction should show up in the scope's secondary pattern. Technician B says this malfunction will not show up in the scope's secondary pattern. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
6. The spark line on an oscilloscope's secondary pattern is almost straight and about one-fourth as high as the firing line. Technician A says this indicates normal ignition system operation. Technician B says this indicates an ignition system malfunction. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
7. Each of the following is an oscilloscope test pattern used by auto technicians *except:*
   (A) raster.
   (B) parade.
   (C) secondary imposed.
   (D) cylinder select.
8. Technician A says low circuit resistance can affect a square waveform. Technician B says high circuit resistance can affect a square waveform. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
9. Technician A says an oscilloscope is one type of test equipment normally used in an engine analyzer. Technician B says a timing light is one type of test equipment normally used in an engine analyzer. Who is right?
   (A) A only.
   (B) B only.
   (C) Both A and B.
   (D) Neither A nor B.
10. A vehicle is brought into the shop with fuel injector problems. Technician A says an engine analyzer can be used to detect certain fuel injector malfunctions. Technician B says an engine analyzer is not capable of testing fuel injector operation. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
11. An engine analyzer normally contains each of the following test instruments *except:*
    (A) multimeter.
    (B) dwell meter.
    (C) test light.
    (D) vacuum gauge.
12. An oscilloscope is being used to test an automobile's ignition system. Technician A increases engine idle speed to about 950 rpm during this test. Technician B increases engine idle speed to about 1500 rpm during this test. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
13. An ignition coil output test is being performed on an automobile. Technician A sets the function controls to the lowest kV range and to raster. Technician B sets the function controls to the highest kV range and to display. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

14. Technician A says that during a scope load test, a defective ignition system component will always produce an abnormal scope pattern at idle speeds. Technician B says that during a scope load test, a defective ignition system component may not produce an abnormal pattern at idle speeds. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.
15. A cylinder balance test is being performed on an automotive engine equipped with a catalytic converter. Technician A says that during this test, each cylinder should be shorted for at least 45 seconds. Technician B says that during this test, each cylinder should not be shorted for more than 15 seconds. Who is right?
    (A) A only.
    (B) B only.
    (C) Both A and B.
    (D) Neither A nor B.

Activities—Chapter 46

1. Study the instruction manual for an analyzer and demonstrate how to hook it up for a test designated by your instructor.
2. With an oscilloscope hooked up and working, point out the three sections of an ignition secondary scope pattern.
3. Interpret the trace patterns of a scope set up to test the ignition system.
4. Scope test several sensors. Make a sketch of the waveform produced by each with a written explanation of your results.